attain their maxima values in 1839 and 1873, and those of the westerly winds in April in 1837 and 1869. As the secular variations of the sunspots have their maxima in 1837·2 and 1870·8, the agreement is in close accord.

There seems little doubt that, during the interval of time covered by the present investigation, the meteorological phenomena, number of auroræ, and magnetic storms, show secular variations of a period of about thirty-five years, the epochs of which harmonise with those of the secular variation of sunspots.

As we are now approaching another maximum of sunspots which should correspond with that of 1870·8, it will be interesting to observe whether all the solar, meteorological, and magnetic phenomena of that period will be repeated.

Conclusion.

1. There is an *alternate* increase and decrease in the length of a sunspot period reckoning from minimum to minimum.

2. The epoch of maximum varies *regularly* with respect to the preceding minimum.

The amplitude of this variation about the mean position is about ± 0·8 year.

The cycle of this variation is about thirty-five years.

3. The total spotted area included between any two consecutive minima varies regularly.

The cycle of this variation is about thirty-five years.

4. There is no indication of the fifty-five-year period as suggested by Dr. Wolf.

5. The climate variations indicated by Professor Brückner are generally in accordance with the thirty-five-year period.

6. The frequency of auroræ and magnetic storms since 1833 show indications of a secular period of thirty-five years.

"On the Variation in Gradation of a Developed Photographic Image when impressed by Monochromatic Light of Different Wave-lengths." By Sir William de W. Abney, K.C.B., D.C.L., D.Sc., F.R.S. Received March 26,—Read May 2, 1901.

Introductory.

When a series of small spaces on a photographic plate are exposed to a constant light for geometrically increasing times, or for a constant time to geometrically increasing intensity of illumination, the spaces so exposed will on development show deposits of silver of different

opacities. These opacities may be measured and noted as "transparencies," "opacities," or "densities," the last being the – log transparencies and the opacity $\frac{1}{\text{transparency}}$. (These definitions of opacity and density are those given by Hurter and Driffield, and are generally understood as such in photographic literature.) Where varying time exposures are given, it is convenient to start with some unit of time, such as 10 seconds for the exposure of the first small space on a plate, to double this exposure for the next small space, and so on. When the measurements of transparency or density are made, and the curve has to be plotted, the scale for the abscissa is conveniently the number of the exposure—that is, the time of exposure in powers of two. The ordinates are then set up as transparency of deposit, total transparency being 100, or as densities which give the absolute light cut off in terms of common logarithms. The curve joining these different ordinates is in both cases approximately a straight line for some distance, and, at each end, tends to become parallel to the scale of abscissæ, and this straight portion is taken as representing the gradation of the plate. If the same plate be thus exposed to different monochromatic lights, and the images developed together and the density measured, it is easily seen from the plotted curves if the "gradation" of the plate is the same in each case, since, if they are, the straight portions of each curve should be parallel.

[It may be noted that the less steep the gradation of a plate, the greater will be the extremes of lights and shades in an object or view that will be shown in a print, as the blackest tone obtainable on it reflects about 3 per cent. of light. For this reason in sun-lighted views, a plate showing a flat gradation should be employed, whilst in those illuminated by a cloudy sky, a plate giving a steep gradation should be used.]

When obtaining the three negatives for three-colour printing where the object is photographed through an orange, a bluish green, and a blue screen, if there is much change in gradation caused by the difference in the colour of the light reaching the plate, the true rendering of an object in its natural colours becomes an operation of extreme difficulty. It was with a view to ascertain if some of the difficulties which have been encountered in this process were due to difference in gradation caused by the different coloured screens, that this research was commenced some three years ago. Nearly two years ago, in an article in 'Photography,' I indicated that a variation in gradation due to difference in the monochromatic light in which the exposure was made did exist, and some six months ago Mr. Chapman Jones, in a paper communicated to the Royal Photographic Society, independently announced the same result from experiments made principally with orthochromatic plates with light passing through various coloured

media, and he generalised from his experiments, that the smaller the wave-length, the less steep was the gradation, the ultra-violet rays giving the least steep, and the red the most steep gradation. My experiments, which had at that time been partially completed, did not bear out this generalisation to the full when pure silver salts were used; and my subsequent measurements with them show that the least steep gradation is that given by the monochromatic light to which the simple silver salt experimented with is most sensitive, and that the gradation becomes steeper as the wave-lengths of light employed depart in either direction in the spectrum from this point, the steepest gradation being given by the extreme red. The case of orthochromatic plates in which is a complex mixture of silver salt and dye, is necessarily less simple, involving considerations of the localities in the spectrum to which the dye or dyes, together with that of the silver salt, are most sensitive. For this reason the simple salts have been experimented with in preference to the more complex organic compounds.

Methods of Experimenting.

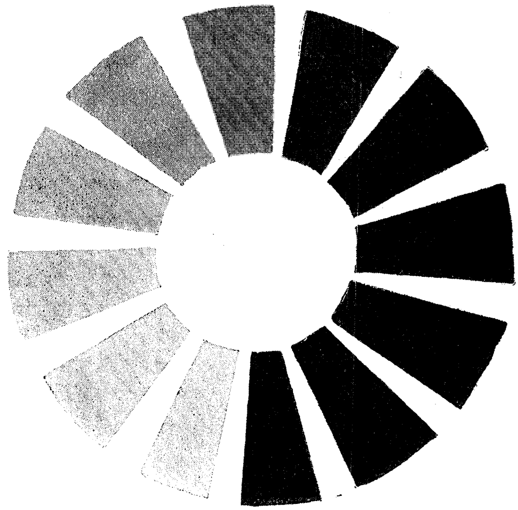
As pointed out in the opening paragraph, there are two ways of experimenting, one where the illumination is constant, the times of exposure being altered, and the other in which the time of exposure is constant, and the illumination is altered. This last is the condition under which an image in the camera is photographed. It might appear that both methods should give identical quantitative results, but it was more than probable that they would not do so, from the experiments that I had previously carried out with these two methods with ordinary white light.

The first set of experiments were with *fixed time of exposure* and varying intensity of light. To obtain the varying intensity, a photographic plate was exposed to white light, the parts exposed being limited to an area having the form of a triangle with the top cut off at the apex, the two sides being radial to the centre of the plate. The enclosed angle was about 20°, so that by turning the plate round its centre, twelve different spaces would be exposed. After the plate had been developed with ortol or ferrous oxalate, fixed, washed, and dried, the intervals between the exposed parts were blocked out. The opacities were then ready for measurement. Fig. 1 is a reproduction of the "star" graduated opacities.

Measurement of Star Opacity with different Colours.

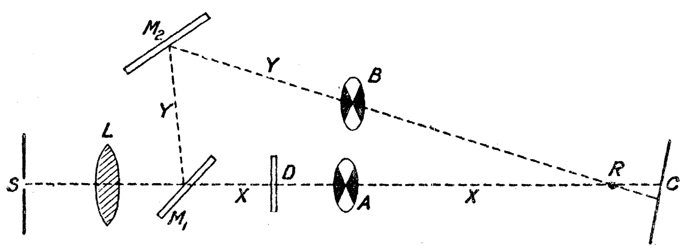
It became necessary to see whether the deposit obstructed light equally for each ray of the spectrum, and the following arrangement was adopted. The colour patch apparatus which I have

FIG. 1.



described in previous papers on Colour Photometry in the 'Philosophical Transactions,' was brought into use. A ray of the spectrum was allowed to issue through S, fig. 2, and after passing through

FIG. 2.



a lens formed a square patch of monochromatic light on C, a white screen. In the path of the beam X a plain glass mirror, M_1, was inserted, which deflected a certain percentage of the beam Y to M_2, a silvered glass mirror, which in its turn reflected Y so as to fall on C. A rod, R, placed in proper position, caused two oblongs of the direct and reflected beams to fall side by side on C. Two sectors, A and B, were placed in the paths of X and Y respectively. The apertures of A could be opened or closed at pleasure whilst the disc was rotating. A red ray of the spectrum first came through S, and the aperture in A required to equalise the two adjacent patches of light was noted. Other rays of the spectrum were similarly dealt with, when it was found that the aperture in A remained unaltered, showing that within the limits of error of observation the percentage of reflec-

tion from M_1 remained the same for all rays. The star-shaped opacities were then introduced into the beam X at D, and when necessary, B was rotated with known and fixed apertures, and the patches of light again made equally bright by means of A. It was found that the apertures of A varied as the different spectrum colours passed through the deposits, forming the graduated star. Using the same scale for the spectrum as used in my former papers (B is 61·3. Li 59·7, C 58·1, D 56, E 39·8, F 30·05, Li 22·8, G 11·2), the absorptions were calculated for the whole spectrum. It was found that the coefficient of absorption (obstruction) of white light and of the ray 26·8, coincided, and taking this as unity (for a purpose which will be seen presently) the coefficients of the other rays are as follows:—

Table I.

Scale number.	Absorption.
59 to 49·8	0·87
47·5	0·90
42·9	0·92
38·3	0·93
33·7	0·95
29·1	0·97
26·8	1·00
22·2	1·02
17·6	1·02
8·4	1·08

The transparencies of the different parts of the star to lamplight were measured and calculated out in powers of -2, the light transmitted through the part on which no deposit appeared being taken as zero. The following are the transparencies as calculated:—

Table II.

Opacity.	Transparency in powers of -2.
No. 1	0
,, 2	0·38
,, 3	0·75
,, 4	1·05
,, 5	1·73
,, 6	2·36
,, 7	3·5
,, 8	4·16
,, 9	5·2
,, 10	5·9
,, 11	6·9
,, 12	8·9

In percentages the transmission of white light through No. 1 and No. 12 is therefore 100 and 0·477 respectively, which allows a sufficiently wide range of intensity to be investigated. The above numbers represent then the absorption of white light, and also that of the blue light coming through a slit placed at 26·8 of the scale of the spectrum. To obtain the scale in powers of -2 for the other rays they must be multiplied by the factors given in Table I.

The star can now be used for the purpose for which it was prepared.

Experiments with Fixed Time of Exposure.

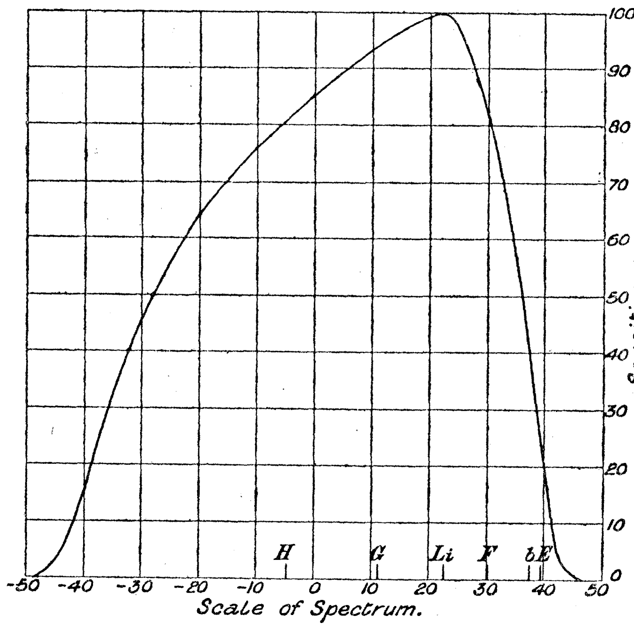
With the colour-patch apparatus a patch of red light was thrown on the star backed by a sensitive plate, which could be revolved round their central point in a special dark slide, and exposure was made to the patch with the plates rotating for the time it was judged necessary to cause an impression of each intensity of light. The rotation was deemed necessary in case the light coming through the thick part of the prism was more absorbed than that coming through the thin part. The plate was then removed from the slide, and a scale of gradation impressed on a part which had been covered up during the previous exposure. The source of light used for this scale was an amyl-acetate lamp placed at 4 feet from the plate, and the time was doubled for each successive exposure. On development there was an image of the star, each space in different densities, and alongside a graduated scale of densities with which the star densities could be compared. Other plates were exposed to other rays of the spectrum, those selected being at the scale numbers recorded in Table I. As each separate image of the star could be compared with the scale of gradation given by the amyl-acetate lamp they could be compared with one another.

Spectrum Sensitiveness of Bromo-iodide of Silver.

The first sensitive salt of silver with which experiments were made was the bromide of silver, to which a small quantity of iodide of silver had been added. A spectrum of the electric arc light was impressed on the gelatine plates prepared with this salt, and the sensitiveness to the various rays ascertained by the plan given in a previous paper.* (To facilitate a comparison of the results given in this paper with the curve of sensitiveness the latter is drawn on the prismatic scale as given above.)

* "The effect of the Spectrum on the Haloid Salts of Silver," Abney and Edwards, 'Roy. Soc. Proc.,' vol. 47. Read December 12, 1889.

FIG. 3.



The following table applies to the curve, fig. 3.

Table III.

Scale No.	Sensitiveness.	Scale No.	Sensitiveness.
42	5	12	95
44	21	8	92
38	35	4	89
36	50	0	85·5
34	63	− 4	82
32	74	− 8	77·5
30	82	−12	73·5
28	89	−16	69
26	96	−20	64
24	99	−28	50
22	100	−36	29
20	99	−42	13
16	97	−48	0

The measurement of the densities on the plates was made by means of an arrangement by which the comparison light was transmitted through a graduated black annulus, whose thickness increased arithmetically with the number of degrees from the zero point. This gave the density measured on a scale of logarithms on a base due to

its coefficient of absorption (obstruction). The mode of measurement has been described in other papers by myself and need not be repeated. As the "star" opacities and the graduated opacity scale on each plate were measured with the same annulus, it was unnecessary to reduce the measurements to densities which are usually taken in terms of common logarithms, or to transparencies in percentages of the initial light.

Example of Experiments.

It will facilitate matters if one example of measures be given in detail, and the mode in which they are applied. The spectrum colour used was at the scale No. 56·7. The star with the plate in contact with it was placed in the dark slide, and so arranged that the square patch of monochromatic red light would cover the whole of the former. The only light which would penetrate to the plate was through the star opacities. The star and plate were made to revolve round their centre in the slide by means of a spindle projecting outside, on which was a pulley that could be geared to an electromotor. Exposure was given for 65 minutes. No light was in the room except the red light. To make certain that the red light which fell on the prisms, and which illuminated them to a certain small extent, had no effect on the plate, the slit S, fig. 2, was covered with red glass, which only allowed the red of the spectrum to pass. The plate after the first exposure was completed; was removed and placed in a special slide, which allowed varying time exposures to be made on small square areas of the plate alongside that part which had been already impressed. The exposures were made to an amyl-acetate lamp at 4 feet distance, and were of 1, 2, 4, 8, &c., units of time duration. The plate was developed with ortol developer, fixed, washed, and dried. It was then placed in the measuring apparatus, and the scale densities of the amyl-acetate lamp exposures and the star opacities measured. On looking at Table I it will be seen that the coefficient of absorption, as there shown, is 0·87. The numbers in Table II were therefore multiplied by 0·87 to give the scale for abscissa in powers of 2. The following measures were obtained (Tables IV and V).

These results were plotted (fig. 4), and straight parts of both curves were compared. It will be seen that in the star opacities the curve cuts the abscissa 1 with an ordinate of 174, and this same ordinate is found on the scale curve at 2·65 in the abscissa. Again, the first has an ordinate of 63 at the abscissa 4, but the scale has abscissa 6·65 for the same ordinate. This shows that the exposures of the star would have had to be prolonged in both cases to have acquired the same density as the scale, but very unequally. We can find the unequal times necessary by subtracting the two abscissæ from one another at each point, and expressing the inequality by a fraction.

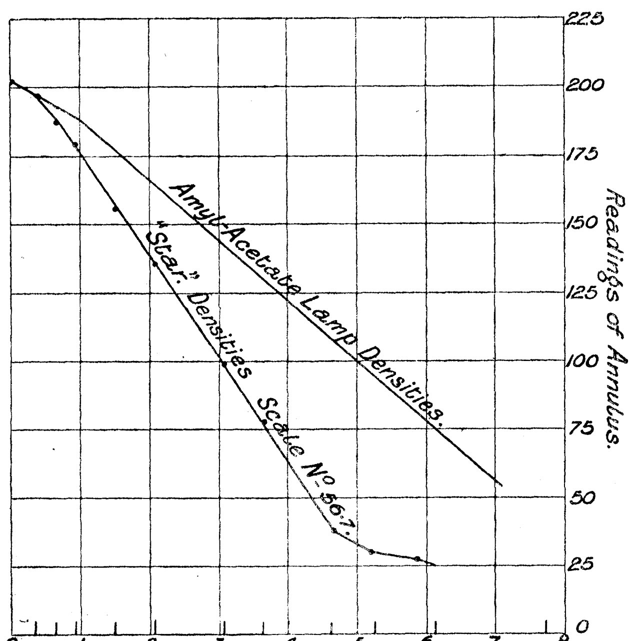
Table IV.

Amyl-acetate scale.	
Exposure in powers of 2.	Reading of Annulus.
1	202
2	189
3	168
4	145
5	122
6	98
7	77
8	55
Bare glass	21

Table V.

"Star" opacities.	
Intensity in powers of −2.	Reading of annulus.
0	202
0·33	197
0·65	187
0·93	178
1·50	156
2·05	136
3·05	97
3·62	77
4·61	39
5·22	30
6·13	26
7·74	—
Bare glass	21

FIG. 4.



Light Intensities for "Star" in powers of -2.
Time of exposure for Amyl-Acetate Lamp in powers of -2.

Thus :—

Abscissa.

	Star.		Scale.
	1	=	2·65 (ordinate 155)
	4	=	7·60 (ordinate 42)
	3	=	4·95
or	1	=	1·65

That is to say, the gradation of the plate when subjected to the red light is much steeper than when subjected to the light of the amyl acetate, and that to produce the same slope the ratio of the times of exposure to red light would have to be shortened in the ratio of 1 : 1·70 ; that is, if the exposure was doubled for the red light on each small space ; then to make the slope the same for the amyl-acetate light the successive exposures given with it would have to be 3·3 times. It must be recollected that the first exposures required to give any deposit on a plate would be widely different, being far larger for the red light.

Results of Measures made.

To avoid any white light with which the prisms were illuminated reaching the plate through the slits, the following absorbing media were placed in front of the slit at the places indicated. The times of exposure are also shown.

Scale No.	Exposure.	Absorbing medium in front of slit.
56·7	65 min.	Stained red glass.
54·4	20 ,,	,, ,,
52·1	5 ,,	,, ,,
50·6	5 ,,	Orange.
47·5	3 ,,	Lemon yellow.
42·9	2 ,,	Chrome green.
38·3	2 ,,	Peacock green.
33·7	10 secs.	,, ,,
29·1	8½ ,,	Blue dye.
26·8	12 ,,	,,
22·2	5 ,,	Cobalt glass and blue dye.
17·6	5 ,,	,, ,, ,,
8·4	4 ,,	Methyl violet.

The following tables give the measured curves, and from them the gradations are found, as in the above example, the exposures given being as follows :—

Table VI.

Wave-lengths.	λ6395		6188	6004	5892	5689		5422		5187		4990		4816		4735		4584		5450		4207	
Scale Numbers.	56·7		54·4	52·1	50·6	47·5		42·9		38·3		33·7		29·1		26·8		22·2		17·6		8·4	
	Intensity.	Density.	Density.	Density.	Density.	Light intensity.	Density.	Light intensity.	Density.	Light intensity.	Density.	Light intensity.	Density.	Light intensity.	Density.	Light intensity.	Density.	Light intensity.	Density.	Light intensity.	Density.	Light intensity.	Density.
	0	202	158	191	176	0	214	0	165	0	202	0	142	0	165	0	180	0	180	0	175	0	197
	0·33	197	148	177	165	0·34	201	0·35	152	0·35	196	0·35	235	0·37	159	0·38	176	0·39	176	0·39	172	0·40	195
	0·65	187	135	165	155	0·68	189	0·64	141	0·66	184	0·68	127	0·73	151	0·75	168	0·76	166	0·76	166	0·79	190
	0·93	178	124	153	145	0·94	180	0·97	128	0·98	176	1·00	120	1·04	145	1·05	165	1·06	157	1 06	163	1·11	184
	1·50	156	103	131	126	1·56	156	1·53	106	1·61	157	1·64	103	1·70	131	1·73	155	1·77	148	1·77	152	1·84	167
	2·05	136	81	108	97	2·12	136	2·17	84	2·19	140	2·25	89	2·32	117	2·35	142	2·40	134	2·40	137	2·62	148
	3·05	97	55	67	65	3·15	99	3·2	58	3·25	110	3·32	70	3·44	95	3·5	119	3·57	112	3·57	109	3·7	128
	3·62	77	40	48	46	3·74	75	3·85	46	3·87	91	3·95	55	4·07	81	4·16	103	4·23	99	4·23	96	4·4	107
	4·61	39	28	31	229	4·77	49	4·9	30	4·95	64	5·05	42	5·2	61·5	5·3	78	5·4	75	5·4	70	5·6	77
	5·22	30	24	26	25	5·4	35	5·5	28	5·66	45	5·7	36	5·9	55	6·0	70	6·1	60	6·1	55	6·35	62
	6·13	26	—	—	—	6·3	28	6·5	—	6·66	39	6·7	31	6·95	44	7·05	55	7·15	48	7·15	42	7·45	56
	7·74	—	—	—	—	8·01	—	8·2	—	8·4	25	8·5	—	8·75	—	8·9	39	9·1	28	9·1	29	9·4	35
	Bare	21	21	21	21	—	22	—	22	—	21	—	21	—	21	—	21	—	21	—	21	—	21

Table VII.—Scales of Gradation taken with the Amyl-acetate Lamp.

Time of exposure in powers of −2.	Densities.												
	(λ6395) 56·7	(λ6188) 54·4	(λ6004) 52·1	(λ5292) 50·6	(λ5689) 47·5	(λ5422) 42·9	(λ5187) 38·3	(λ4990) 33·7	(λ4816) 29·1	(λ4735) 26·8	(λ4584) 22·2	(λ4450) 17·6	(λ4207) 8·4
0	202	187	225	208	235	227	187	180	175	170	172	170	175
1	189	167	213	184	220	202	162	162	153	158	151	158	155
2	168	145	187	160	187	172	139	142	131	137	130	137	135
3	145	120	160	139	165	143	114	122	110	116	109	115	114
4	122	96	133	113	135	114	90	102	88	94	88	93	95
5	93	72	105	88	106	85	66	83	72	73	67	72	74
6	77	54	75	65	76	68	50	62	56	56	49	51	55
7	55	40	54	50	50	53	40	55	46	44	35	44	44
Bare glass....	21	21	21	21	22	22	21	21	21	21	21	21	21

Table VIII.

Scale No.	56·7	54·4	52·1	50·6	47·5	42·9	38·3	33·7	29·1	26·8	22·2	17·6	8·4
Gradation compared with amyl-acetate light.	1·65	1·63	1·48	1·45	1·35	1·3	1·18	1·08	0·98	0·98	0·95	1·05	1·10

Fig. 5 gives the results as shown in bottom line of the table. It will be seen that the slopes of the gradation of the different parts of the spectrum are least when near the maximum photographic effect (compare fig. 5 with fig. 2) and greatest in the red.

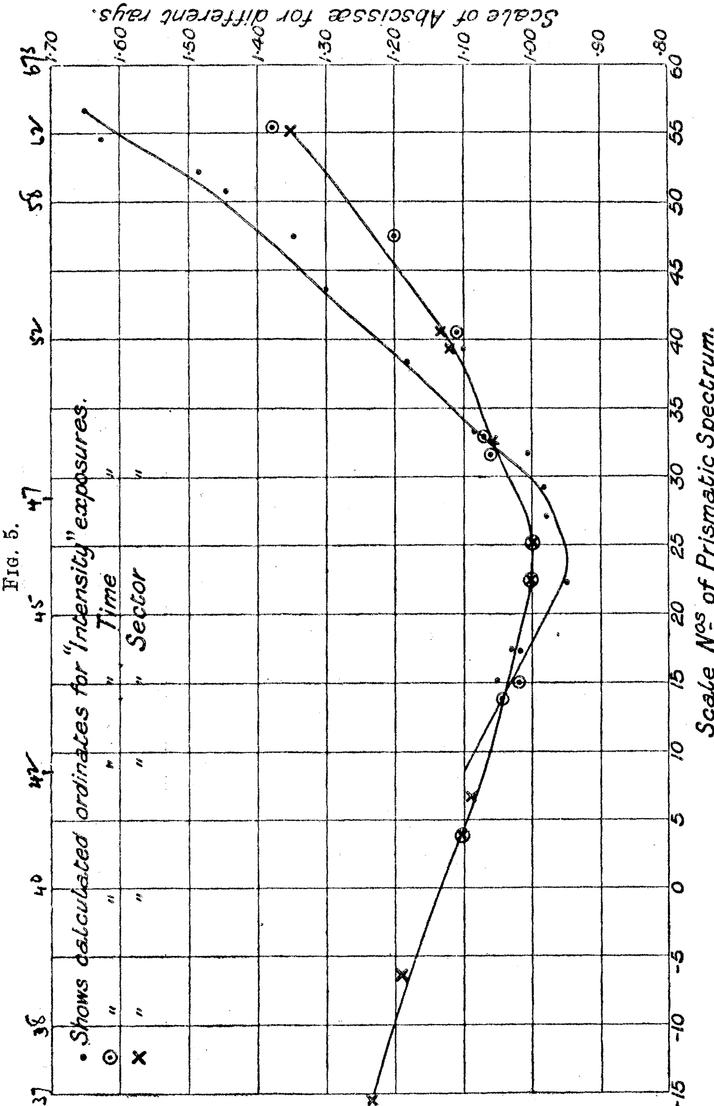


FIG. 5.

Experiments with Fixed Intensities of Rays.

Before commenting on this curve it will be better to describe the next set of experiments in which the light is constant, and there is a change in time.

The arrangements made were as follows:—Four slits in a card were made of such convenient width as (found by trial) allowed four different rays of the spectrum to emerge, and in front of the slits were cemented strips of a spectacle lens, which each gave an image of the prism surface of small size, but alongside one another. To prevent the white light which illuminated the prisms causing any error in the exposure, in front of each slit was placed a strip of glass of a colour approximately corresponding to the colour coming through it. Exposures were made to the four colours in the same plate and for the same length of time, the exposure being admitted or shut off at the slit of the spectroscope, and when completed the plate was given a graduated scale with the amyl-acetate lamp as before. The development of the plate was then carried out and the densities measured as usual.

The curve of the amyl-acetate light was plotted first, and the places which corresponded to the density of the "blue" light scale was marked on it. It was necessary to do this, for although the electric arc light was steady, yet it did not remain absolutely the same in intensity throughout the whole of the exposures. The places so fixed on the scale made by the amyl-acetate lamp by the blue exposures gave the points in the abscissa to which to refer the ordinates of the three other colour curves. These were duly set up and the curves drawn. Fig. 6 shows Table IX drawn diagrammatically. It was again found that the gradation given by the colours less refrangible than the Scale No. 24 were steeper than that of this No., as were also those of the colours more refrangible.

The slits were then moved into new positions and the same process gone through. (See Tables IX, X, and XI.) When these gradation factors are plotted on their appropriate scale numbers we get a curve convex to the base, with the lowest part lying about Scale No 24, confirming the results obtained by the previous place. (See fig. 5.) There can be but little doubt from both of these results that the place of minimum gradation given by rays is close to the wave-length to which the salt of silver under consideration is most sensitive.

Fig. 6.

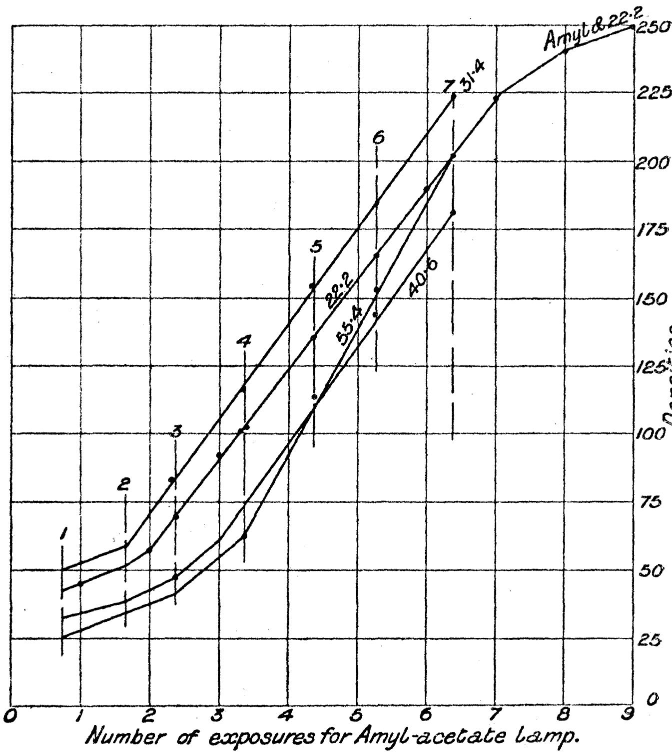


Table IX.

Amyl-acetate.		Scale numbers.							
		55·4 (λ 6277)		40·6 (λ 5300)		31·4 (λ 4901)		22·2 (λ 4584)	
E	D	E	D	E	D	E	D	E	D
1	47	1	26	1	33	1	51	1	42
2	60	2	35	2	43	2	61	2	53
3	93	3	42	3	47	3	85	3	70
4	126	4	63	4	73	4	118	4	101
5	159	5	114	5	110	5	155	5	135
6	192	6	151	6	144	6	187	6	165
7	225	7	202	7	186	7	225	7	202
8	242								
9	250								

Table X.

Amyl-acetate.		Scale numbers.							
		39·3 (λ 5326)		25 (λ 4675)		15 (λ 4377)		6·6 (λ 4162)	
E	D	E	D	E	D	E	D	E	D
1	55	1	43	1	43	1	55	1	53
2	70	2	47	2	47	2	60	2	59
3	94	3	74	3	87	3	101	3	108
4	128	4	82	4	92	4	108	4	115
5	162	5	127	5	133	5	152	5	161
6	198	6	143	6	147	6	164	6	177
7	228	7	167	7	169	7	186	7	201
8	240	8	190	8	190	8	208	8	223
9	250								

Table XI.

Amyl-acetate.		Scale numbers.							
		47·4 (λ 5683)		32·7 (λ 4952)		22·8 (λ 4602)		14·5 (λ 4364)	
E	D	E	D	E	D	E	D	E	D
1	75	1	66	1	45	1	77	1	105
2	99	2	108	2	61	2	113	2	142
3	123	3	134	3	83	3	134	3	163
4	147	4	165	4	110	4	164	4	191
5	171	5	193	5	135	5	182	5	214
6	195	6	202	6	143	6	190	6	223
7	217								

In the above tables, E is exposure and D is measured opacity in degrees of the annulus.

Table XII.

From Table IX.		From Table X.		From Table XI.	
Scale number.	Gradation factor.	Scale number.	Gradation factor.	Scale number.	Gradation factor.
55·4	1·38	39·3	1·10	47·4	1·20
40·6	1·11	25	1·00	32·9	1·07
31·4	1·06	15	1·02	22·8	1·00
22·2	1·00	6·6	1·10	14·5	1·04

The "Gradation factor" is the alteration required in the abscissa when expressed in powers of 2, the scale No. 22·2 having abscissa of unit length.

Table XIII.—Exposures to Amyl-acetate.

No.	Time in seconds.
1	1
2	2
3	4
4	8
5	16
6	32
7	64
8	128
9	256

Table XIV.—Exposures for Monochromatic Rays.

No.	Time in minutes and seconds.
1	5″
2	10″
3	20″
4	40″
5	1′ 20″
6	2′ 40″
7	5′ 20″
8	10′ 40″

Experiments with Fixed Intensities of Rays, and Times of Exposure varied by means of a Rotating Disc.

Still one more plan, however, remained to be tried, viz., with a fixed intensity of light, but an alteration in the time of exposure by rotating a disc with gradually increasing apertures before the plate. The disc so pierced is shown in fig. 7. It will be seen that there are two apertures, one near the centre and another at the extreme outside of the radius, which include 40° only. There are thus three apertures of 40°, and if the patch of light is uniform the readings of the three should be the same. All the plate was covered by a mask except a portion ½-inch wide which extended its whole length, so that successive portions might be exposed to rays of different wave-lengths at first. The exposed strip of plate was placed in a horizontal direction, *i.e.*, a direction at right angles to the edges of the prisms, and it was then found that the three readings of the 40° apertures

were not the same. To ascertain the cause of this an exposure was made through the slit without any disc intervening, and on develop-

FIG. 7.

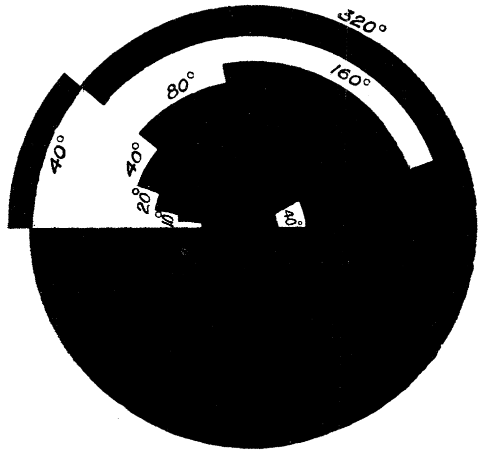
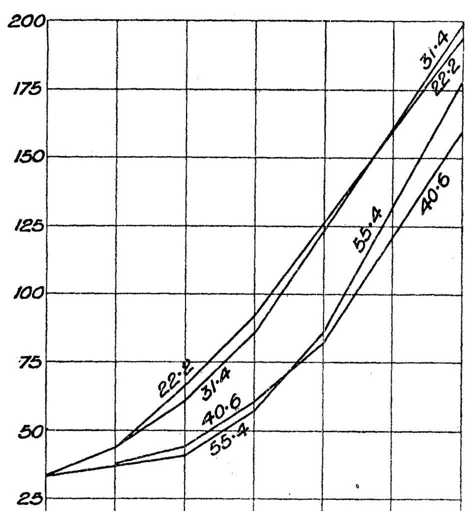


FIG. 8.



Apertures of Sectors in degrees.

ment it was found that the reduction of silver was greatest in that part which was illuminated by the light coming through the edge of the prism, and least where it passed through the bases of the prism,

showing that the glass of the prisms absorbed a certain proportion of the different rays as they passed through. It appeared probable that if the length of the ½-inch-wide slit were placed vertically in the patch of light (*i.e.*, parallel to the edges of the prism) no difference in absorption would be found. Such proved to be the case; the exposure through the slit and the patch of light without the intervening sectors gave a uniformly dense deposit, and when the sectors were replaced the densities given by the three 40° exposures were the same. On each plate exposures were given to four different colours, the total exposure varying in each case according to the colour; a single exposure was also given to some colour without the sector, and an exposure to an amyl-acetate lamp was also given. The following tables give the results obtained, and fig. 8 the results shown diagrammatically of Table XV, and the combined results are shown in fig. 5.

Table XV.—Densities.

Aperture of sectors.	Scale number.			
	55·4 (λ 6277)	40·6 (λ 5300)	31·4 λ 4901	22·2 λ 4584
°				
5	35	37	45	45
10	42	44	60	65
20	57	60	85	90
40	82	80	122	125
80	130	119	160	160
160	178	159	197	195

Table XVI.—Densities.

Aperture of sectors.	Scale number.			
	39·3 (λ 5320)	25 (λ 4675)	15 (λ 4377)	6·6 (λ 4162)
°				
5	53	75	75	53
10	67	98	100	60
20	89	121	125	82
40	115	144	150	107
80	140	167	174	133
160	166	190	198	157

Table XVII.—Densities.

Aperture of sectors.	Scale number.			
	17·6 (λ 4450)	3·3 (λ 4100)	−6·7 (λ 4130)	−15·8 (λ 3940)
5°	60	78	85	93
10	75	95	102	119
20	97	118	127	145
40	118	142	153	171
80	140	165	171	185
160	152	185	187	192

Table XVIII.—Densities.

Aperture of sectors.	Scale number.		
	32·7 (λ 4952)	22·8 (λ 4602)	14·5 (λ 4364)
5°	35	77	45
10	41	101	57
20	58	124	75
40	72	146	99
80	90	169	122
160	114	192	147
320	138	202	171

Table XIX.

Scale number.	Gradation factor.	Scale number.	Gradation factor.	Scale number.	Gradation factor.
55·4	1·35	25·0	1·00	−6·7	1·19
40·6	1·13	15·0	1·05	−15·8	1·23
31·4	1·05	6·6	1·09	32·7	1·05
22·2	1·0	17·6	1·025	22·8	1·00
39·3	1·12	3·3	1·10	14·5	1·04

It will be seen that these gradation factors are very closely the same as those obtained by the other plan of altering the time exposures, the intensity of the light acting remaining the same. The curve in these results has been pushed further into the ultra-violet than in the other experiments.

Causes of Difference of Results in the Experiments.

We next have to consider the cause of the difference between the results obtained when the intensity of the light was altered, the time being fixed, and these last two sets of results. I must refer to a paper which appeared in the 'Proceedings' of the Royal Society in 1893, entitled "On a Failure of the Law in Photography," &c., more particularly to the Addendum of July 4th, when it was shown that though the product of time of exposure and intensity of light remained constant, yet when the intensity was diminished the photographic action might also be less, and that when the intensity became very small, the diminution was very marked. These observations were further developed in subsequent communications to the Royal Photographic Society, in the same year, and it was shown that when the intensity of the same light remained constant during a set of exposures, the time being altered, the gradation of the plate remained the same though the curves occupied very variable positions in relation to the scale of abscissæ. Thus if with a light of a unit intensity exposures were given to different parts of a plate for, say, 1, 2, 4, 8, &c., seconds, and the light was reduced for another set of exposures on the same plate to 1/100 unit, and in order to make time × intensity constant in both cases the exposures were prolonged to 100, 200, 400, 800, &c., seconds, on plotting the densities of the deposit in the manner described above, the two curves would be strictly parallel though by no means coincident.

In the last two sets of experiments as the relative times of exposure are kept the same, though the intensity is small, the gradation of the different rays would be the same, however much the intensity was increased. On the other hand, where the intensity of the light is small (and when we say intensity, we mean the photographic intensity), the gradation would be steeper than would be the case if the intensity of the light were large. The photographic intensity of the light used for the red ray is less than 1/500 of the blue: hence on this account alone the "gradation factor" is larger than in the last two sets of experiments. This accounts for the difference between the gradation factors obtained by the two methods, from the red to the blue, and also for the approximate coincidence from the blue to the extreme violet when the photographic intensities of the light used are nearly the same. We see, then, that the gradation factors as found by the last two methods are those which really represent the difference due to the alteration in wave-lengths of the monochromatic light, and that the factors found by the first method are compounded between this alteration and that due to diminished photographic intensity.

As before remarked, the results of the first method of experimenting are those which apply to camera images, for they are formed by different intensities of light, and the exposure is the same for any part. If, then, a plain surface were covered with a graduated scale

of greys, and a photograph taken of it through red glass, which practically cuts off all spectral rays except the red, and also through blue glass, the gradation of greys in the negative would be much more pronounced in the case of the red image than that of the blue, and we come to the conclusion that for three-colour photographic printing from a "red," a "green," and a "blue" negative this difference should be a source of difficulty, and this is certainly the case.

What scientific explanation there is of this difference in true gradation factor is hard to say. It almost appears that in the case of the blue waves acting on the atoms of the molecule of sensitive salt, whilst the amplitude is increased the rate of oscillation is slightly altered, gradually making the periodic motion of the waves of light out of tune with the motions of the atoms; whilst with the red rays, which are vastly out of synchronism with the atomic swings, the atoms got more nearly synchronous with them, and thus produce more photographic action. In my work on 'The Action of Light in Photography,' I have given a possible explanation of the difference in effect caused by a feeble intensity and a great intensity of light, and it may be that the same kind of explanation might hold good in this newly found phase of the action of light. It appears that these photographic phenomena are worthy of attention from the point of view of molecular physics.

It may be thought that these results might be peculiar to the salt of silver experimented with. A further series of experiments were conducted with the chloride of silver in gelatine. The maximum sensitiveness of these plates was found to be near H in the solar spectrum. The gradation was found to be least at this point, and increased when rays on each side of this point were employed to act on the film. In the blue near the F line, where the sensitiveness of the plate was very small, the gradation was excessively steep, as it also was in the extreme ultra-violet.

Wave-lengths for Prismatic Scale.

The following table shows the wave-lengths of the scale Nos. :—

Scale No.	λ.	Scale No.	λ.
60	673	28	478
58	652	24	464
56	633	20	452
54	615	16	440
52	600	12	430
50	585	8	420
48	572	4	410
44	548	0	400
40	527	−10	381
36	508	−20	364
32	492		

FIG. 1.

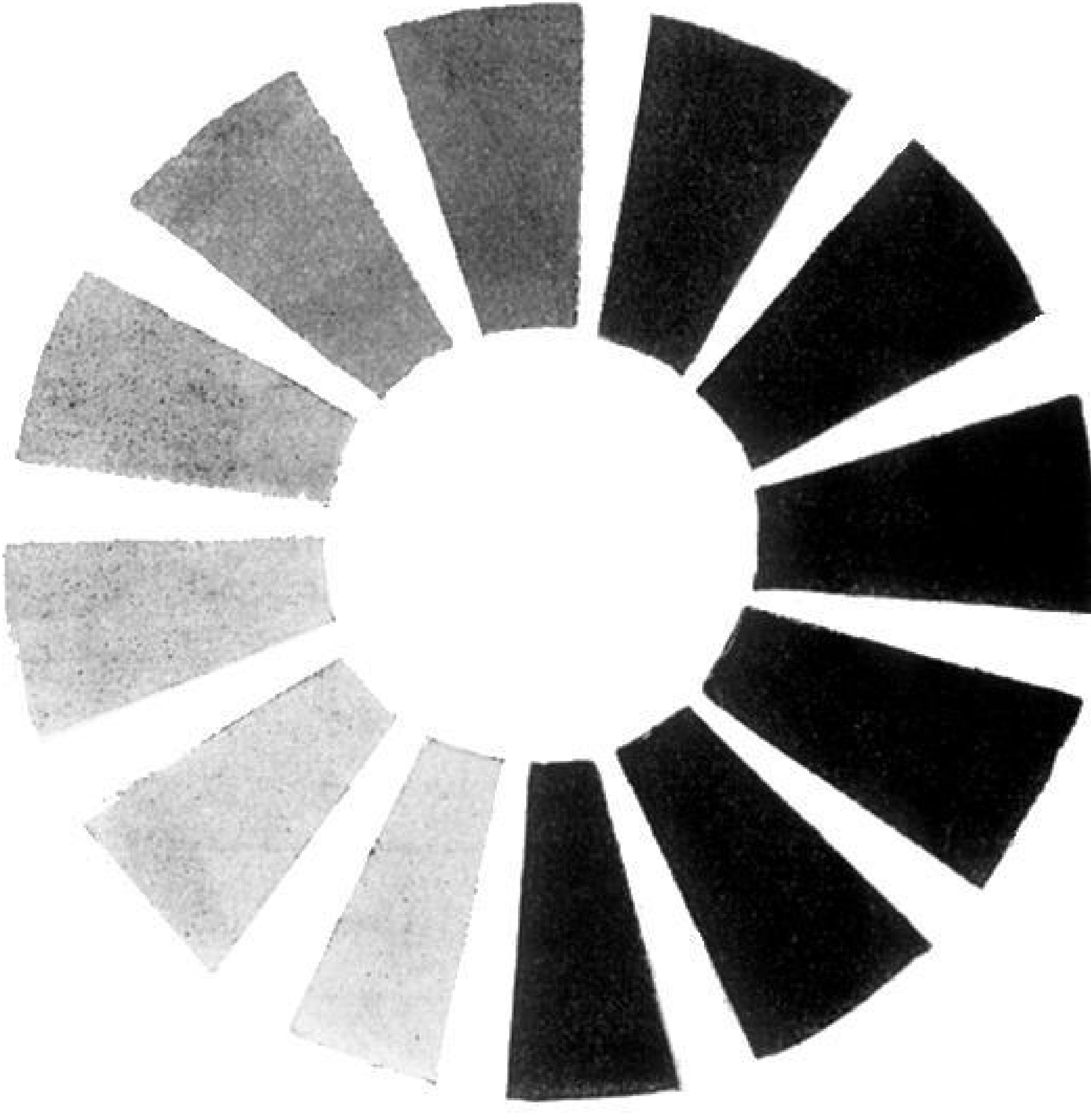


Fig. 7.